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A 1MWe power plant using waste wood fuel is to be installed at a US Marine Corps base, which will supply all wood from a landfill site. The core energy conversion technology is a down-draft gasifier supplying approximately 150 Btu/scf gas to both spark ignition and Diesel dual-fuel engine-generator sets. Features of the plant design include 1)grinding wood fuel from a wide range of waste resources, 2)specialized screening for fines removal, 3)complete tar and other waste product control without landfill disposal, and 4)use of process heat for bulk fuel drying, gasifier air pre-heating, and wastewater evaporation.

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INDEPENDENT POWER PLANT USING WOOD WASTE

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Abstract -- A 1 MWe power plant using waste wood fuel is to be installed at a US Marine Corps base, which will supply all wood from a landfill site. The core energy conversion technology is a down-draft gasifier supplying approximately 150 Btu/scf gas to both spark ignition and Diesel dual-fuel engine-generator sets. Features of the plant design include 1) grinding wood fuel from a wide range of waste resources, 2) specialized screening for fines removal, 3) complete tar and other waste product control without landfill disposal, and 4) use of process heat for bulk fuel drying, gasifier air pre-heating, and wastewater evaporation.

1. INTRODUCTION

Utilizing waste wood as a fuel for electrical power generation theoretically produces zero net gain of carbon dioxide (CO_2) and other greenhouse gases, essentially eliminates sulfur dioxide (SO_2) emissions, reduces air toxic emissions, and helps solve water and solid waste disposal problems. Wood waste energy conversion also provides savings from decreasing or eliminating landfill and fossil fuels costs, possible tax credits, and energy security by using indigenous fuel.

Research Triangle Institute (RTI) is collaborating with the US Environmental Protection Agency (EPA) to design, install and operate a wood gasification power plant that will demonstrate these benefits. This energy project is also intended to provide the impetus for the development of equipment, design of systems, creation of markets, and promotion of exportable technologies. The demonstration plant is to be installed at the Marine Corps Base Camp Lejeune located on the Atlantic coast of the State of North Carolina. The Camp Lejeune Energy from Wood (CLEW) plant will produce at least 1 MW of electrical output using wood gas operated engine-generator sets.

Military bases can optimally utilize waste wood and provide an excellent operational example for industrial sites, small municipalities, and developing regions which could benefit from biomass energy conversion. Expansion of the example could make a real contribution toward meeting US government directives to stabilize CO_2 emissions at 1990 levels by the year 2000 and to reduce Federal agencies' energy consumption to 20% below 1991 levels by the year 2000. The project also has excellent potential for technology transfer to the commercial sector and other public agencies, which follows a trend of revived commercial interest in wood energy and growth of independent power production and industry-site power plants.

The specific plant design emphasizes operational simplicity, minimal use of such resources as ground- or surface-water reserves, minimal waste disposal, fuel preparation from practically any form of wood waste, moderate-risk technology, and low capital investment. The design is intended for plants smaller than 10 MWe which are considered by RTI to present the best opportunity for wood waste utilization and widespread application. This conclusion is based both on studies in North Carolina (which is one of the top 3 States in the US for timber harvesting and wood products) and on studies of waste wood resources throughout the US [1, 2]. While electrical generation was a criterion set by EPA, it was also decided that the complexities of co-generation or combined cycles would not be implemented, because of the desired small scale and the priorities of the Marine base.

2. PROCESS DESIGN

Camp Lejeune occupies approximately 153,000 acres (620 km^2), with 45,000 active duty personnel, 4,500 civilian employees, and about 12,000 dependents. The Base utility is 30 to 40 MW average, with peak summer demand reaching a maximum 70 MW. The 1 acre (4047 m^2) CLEW site has easy access to utilities, is in close proximity to the landfill, and is secluded from the main section of the Base. The wood waste is generated by activities on the Base, providing up to 22,000 tons per year of demolition waste, tree trunks and limbs, pallets and shipping crates, most of which are currently being landfilled.

The site at Camp Lejeune was selected in the autumn of 1994 and the basic energy conversion technology was selected in the winter of 1994. Existing process designs were reviewed on the basis of criteria included in Table 1, and by evaluating developers of small-scale, wood-fueled processes. Wood combustion with an air turbine was considered interesting for its simplicity and novelty to industry applications but was downgraded based on estimated energy inefficiency and development immaturity. Wood boilers and turbines offered nothing new and deficiencies in engineering and corporate soundness eliminated other prospects. A gasification, reciprocating-engine-with-generator process (Avg. Score = 3.4) proposed by Mech-Chem Associates, Inc. of Norfolk, MA was chosen. CLEW system design began in the spring of 1995, and design review, site preparation and equipment orders are underway at this time. Installation should be completed in the spring of 1996, and testing and demonstration will be completed by August 1997. The Marine Corps will then take over full operation of the CLEW plant.

Table 1. Wood-fuel Process Selection Criteria and Rankings

	Combustion & steam turbine	Combustion & air turbine	Gasifier & gas turbine	Gasifier & engine	Gasifier & steam turbine
[illegible]	5	[illegible]	1	[illegible]	3
[illegible]	1	[illegible]	3	[illegible]	2
[illegible]	5	[illegible]	4	[illegible]	2
[illegible]	2	[illegible]	3	[illegible]	1
[illegible]	3.0	[illegible]	2.0	[illegible]	1.0

The Mech-Chem technology consists of a down-draft gasifier (near-atmospheric-pressure, moving-bed, co-current fuel and air flow), gas cleaning components, and spark-ignited or Diesel engines. Other unit operations and project requirements include fuel handling, drying, screening, and transport, process instrumentation and control, performance analysis, and char, water and organics handling for environmental compliance and byproduct uses and sales.

Figure 1 is a simple system diagram. The synthesis gas exits the gasifier and flows through a cyclone, heat exchangers, gas/liquid separators, and cartridge filters. The suction in the system is created by pulling the gas through a multistage centrifugal blower.

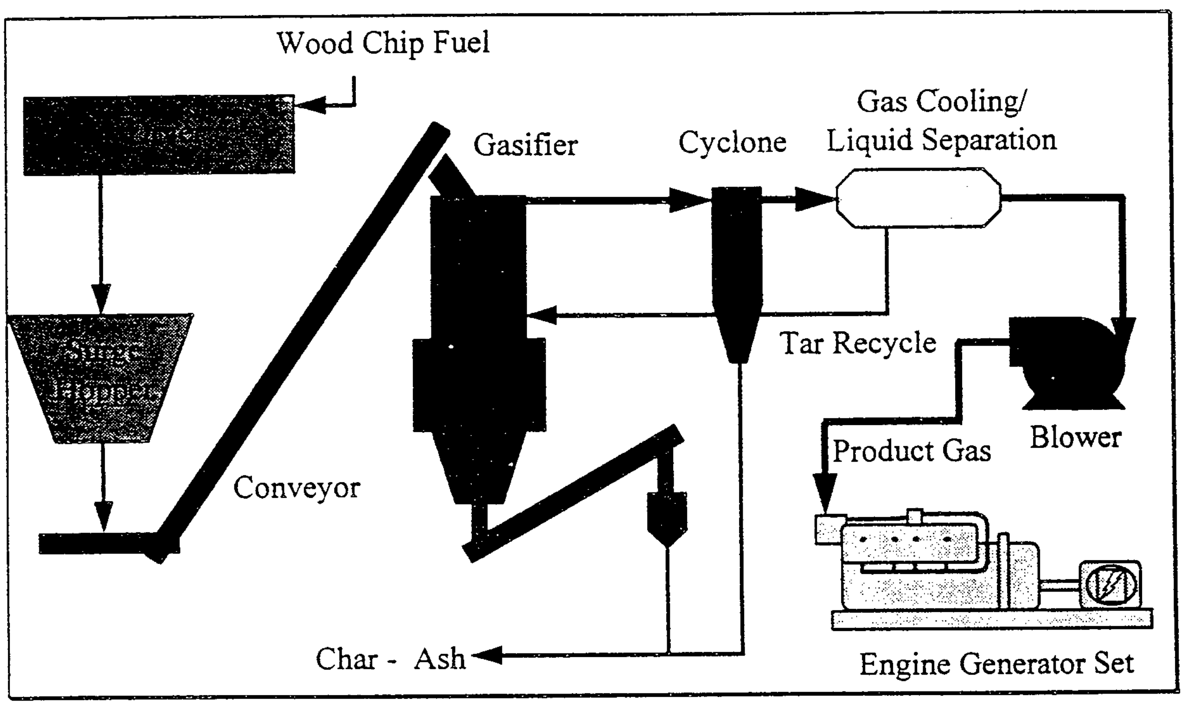

Fig. 1. Process Flow Diagram

Fuel is produced by a landfill-located tub grinder using a hammer mill to reduce any type of waste wood to slices and chunks in a range from about 0.1 gram to 50 grams. The fuel is screened both before loading onto walking floor trailers and at the plant to reduce fines and pressure drop across the gasifier. The fuel drying for the process will be performed in a low-cost, deep bed bulk dryer. The wood fuel will be fed to the gasifier via the dryer at a rate of approximately 2500 lb/hr (1134 kg/hr). More than 5000 scfm (2.45 m^3/s) of engine exhaust and air at 4000F (2040C) will be used to dry the wood to 10% moisture. Tests have been performed by RTI to confirm the drying rate, retention time, and pressure drop associated with the deep bed dryer. The hot exhaust will be pulled through the dryer by a 5 HP (3.7 kW) blower, and a cyclone will separate fines entrained in the air stream leaving the dryer.

The gasifier partially combusts wood near the top of the fuel bed and pyrolyzes the remainder into a low heat value gas and fixed carbon char. Combustion air is preheated in a product-gas-to-air heat exchanger. The gasifier's deep char bed cracks essentially all tars to lighter species, eliminating even most light oxygenates. The char is removed from the bottom of the reactor by a screw conveyor and is collected in carbon hopper to be used as either activated carbon, boiler fuel, or recycle to the gasifier.

A product gas stream cyclone removes particulates, and the stream is progressively cooled and filtered to levels compatible with the blower's limits. The blower adds heat to the product gas which must then be further cooled in a final water-to-gas heat exchanger and a liquid separator which recovers over 90% of the moisture from the fuel and air, which is sparge evaporated using waste heat. A final filter removes sub-micron tars and other aerosols for final engine combustion of the fuel gas. The gas is monitored continuously for constituents such as nitrogen, hydrogen, carbon monoxide, carbon dioxide, and methane. Two engines will be operated -- a 100 to 200 MWe Diesel compression engine that requires mixing up to 10% (by heat value) Diesel fuel with the syngas and a spark-ignited engine modified for volatile gas operation. The efficiency and reliability of the two engines will be compared.

3. PRELIMINARY SYSTEM TEST

In June of 1995, a down-draft gasifier of similar size and design was tested by the CLEW project team at Ellicottville Energy in New York State. The test emphasis was to examine the performance of a CLEW-type fuel for the first time in such a gasifier.

Wood was processed through a tub grinder, requiring modifications to the fuel handling system at the facility. A gas chromatograph for semi-continuous syngas analysis was installed upstream of the 400 MWe Caterpillar spark ignition engine. The process was only operated for about 10 hours after startup because of blockage in a char removal component and failure of a fuel conveyor. Tars and light oils (about 0.003 kg per kg fuel) were produced as a result of low gasifier temperatures and were saved for analysis. Product gas composition and quality (see Figures 2 and 3) were reasonably consistent in spite of system upsets and crude controls. The ground wood fuel behaved well compared to performance with wood pellets of uniform size. Pressure drop was not excessive and the char passed easily through the grate system and showed

excellent devolatilization and carbon conversion levels. The engine performed satisfactorily with the syngas at idle conditions (electrical grid load was not imposed).

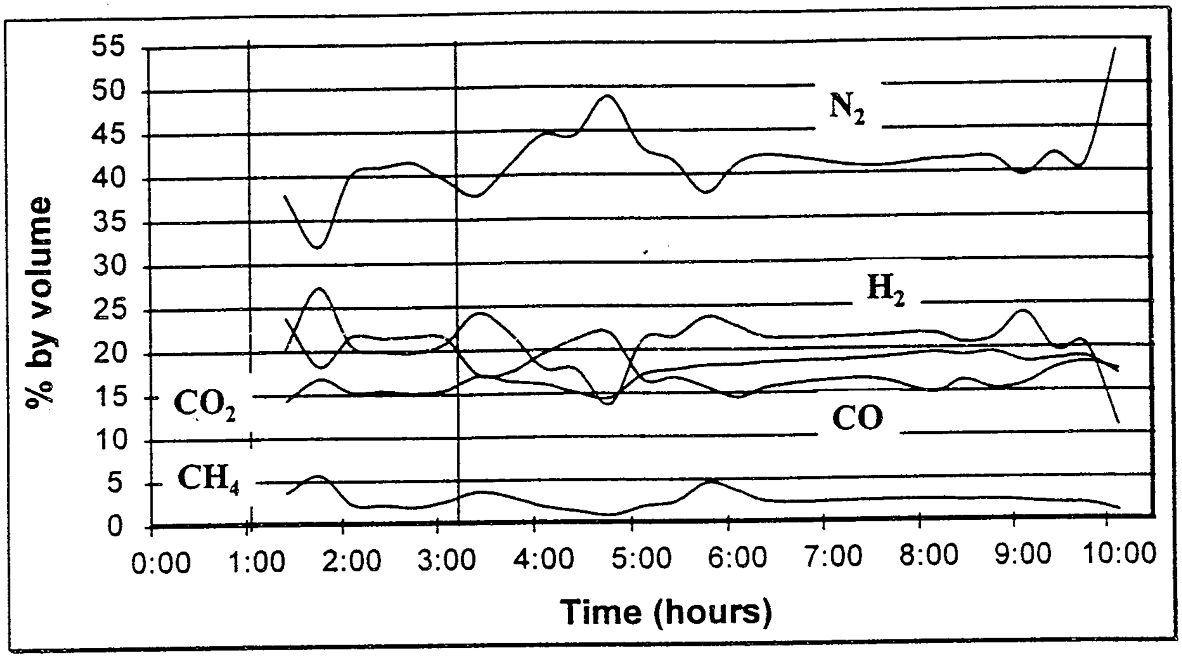

Fig. 2. Continuous Gas Analysis

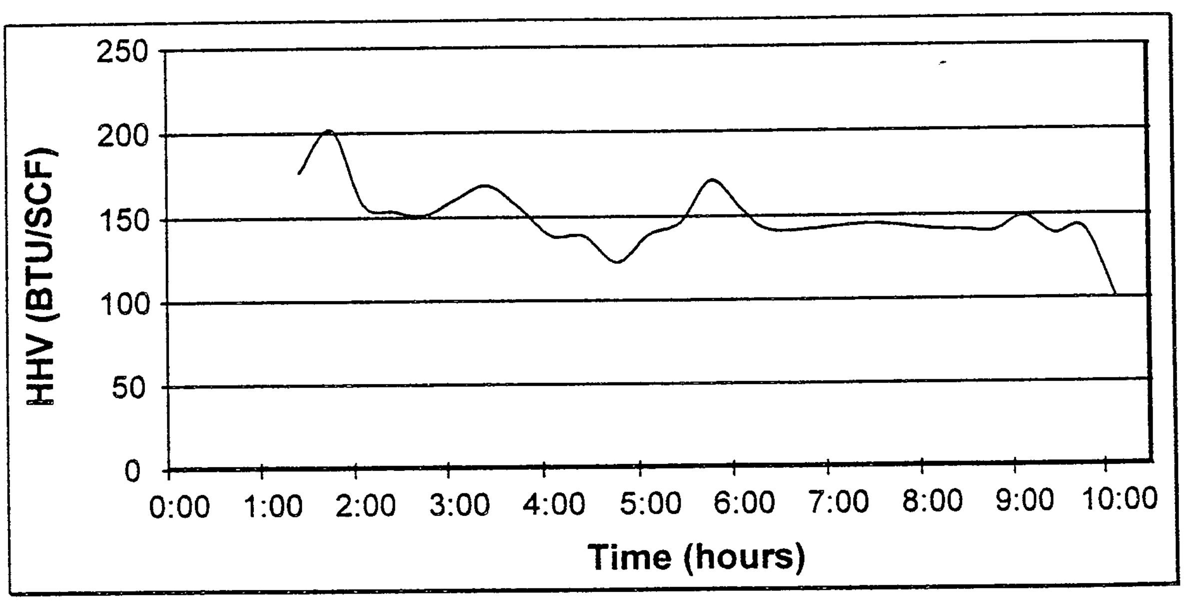

Fig. 3. Heating Value of Product Gas

4. CONCLUSION

The CLEW project is proceeding on schedule and no insurmountable barriers are seen to a successful plant operation. Unique designs for fuel preparation and drying, waste heat recovery and byproduct control remain to be demonstrated.

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